EXHIBIT E

TO THE DECLARATION OF ARPITA BHATTACHARYYA IN SUPPORT OF ASETEK DANMARK A/S'S MOTION FOR PARTIAL SUMMARY JUDGMENT

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If Required, Foreign Filing License Granted: 08/12/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 61/512,379**

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Title

FLUID HEAT EXCHANGE SYSTEMS

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FLUID HEAT EXCHANGE SYSTEMS

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RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 60/954,987, filed on August 9, 2007, and pending U.S. Patent Application No. 12/189,476, filed on August 11, 2008, which patent applications are hereby incorporated by reference in their entirety, for all purposes.

BACKGROUND

The innovations and related subject matter disclosed herein (collectively referred to as the “disclosure”) generally pertain to fluid heat exchange systems. Some systems are described in relation to electronics cooling applications by way of example, though the disclosed innovations may be used in a variety of other applications.

Fluid heat exchangers are used to cool electronic and other devices by accepting and dissipating thermal energy therefrom.

Fluid heat exchangers seek to dissipate to a fluid passing therethrough, thermal energy communicated to them from a heat source.

Despite the existence of many previously proposed fluid heat exchange systems, there remains a need for heat exchange systems configured to provide improved thermal performance. As well, there remains a need for systems configured for existing and developing small form factors, and more particularly. For example, there remains a need

for low-profile heat exchange assemblies (e.g., integrated heat sink and pump assemblies) having a vertical component height of ____ inches, or less. There also remains a need for integrated components and systems having fewer fluid connections. In addition, there is a need for low-pressure-loss flow transitions in integrated heat exchange components.

SUMMARY

The innovations disclosed herein overcome many problems in the prior art and address the aforementioned, as well as other, needs. The innovations disclosed herein pertain generally to fluid heat exchange systems and more particularly, but not exclusively, to approaches for integrating components in such systems. For example, some innovations are directed to low-profile pump housings. Other innovations are directed to heat sink designs that deliver improved heat-transfer and/or pressure-loss performance. And other innovations are directed to approaches for eliminating system components while retaining their respective functions.

In accordance with a broad aspect of the innovations disclosed herein, there is provided a fluid heat exchanger comprising: a heat spreader plate including an intended heat generating component contact region; a plurality of microchannels for directing heat transfer fluid over the heat spreader plate, the plurality of microchannels each having a first end and an opposite end and each of the plurality of microchannels extending substantially parallel with each other microchannel and each of the plurality of microchannels having a continuous channel flow path between their first end and their opposite end; a fluid inlet opening for the plurality of microchannels and positioned between the microchannel first and opposite ends, a first fluid outlet opening from the plurality of microchannels at each of the microchannel first ends; and an opposite fluid outlet opening from the plurality of microchannels at each of the microchannel opposite ends, the fluid inlet opening and the first and opposite fluid outlet openings providing that any flow of heat transfer fluid that passes into the plurality of microchannels, flows along

the full length of each of the plurality of microchannels in two directions outwardly from the fluid inlet opening.

In accordance with another broad aspect of the disclosed innovations, there is provided a method for cooling a heat generating component comprising: providing a fluid heat exchanger including a heat spreader plate; a plurality of microchannels for directing heat transfer fluid over the heat spreader plate, the plurality of microchannels each having a first end and an opposite end and each of the plurality of microchannels having a continuous channel flow path between their first ends and their opposite ends; a fluid inlet opening for the plurality of microchannels and positioned between the microchannel first and opposite ends, a first fluid outlet opening from the plurality of microchannels at each of the microchannel first ends; and an opposite fluid outlet opening from the plurality of microchannels at each of the microchannel opposite ends; mounting the heat spreader plate onto the heat generating component creating a heat generating component contact region where the heat generating component contacts the heat spreader plate; introducing a flow of heat exchanging fluid to the fluid heat exchanger; urging the flow of heat exchanging fluid through the fluid inlet into the plurality of microchannels first to a microchannel region between the ends of the microchannel; and, diverting the flow of heat exchanging fluid into a plurality of subflows that each flow away from the other, a first of the plurality of subflows flowing from the fluid inlet toward the first fluid outlet and a second of the plurality of subflows flowing from the fluid inlet toward the opposite fluid outlet.

It is to be understood that other innovative aspects will become readily apparent to those skilled in the art from the following detailed description, wherein various embodiments are shown and described by way of illustration. As will be realized, other and different embodiments are possible and several details are capable of modification in various other respects, all without departing from the spirit and scope of the principles disclosed herein.

Accordingly the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Unless specified otherwise, the accompanying drawings illustrate aspects of the innovative subject matter described herein. Referring to the drawings, wherein like reference numerals indicate similar parts throughout the several views, several aspects of the presently disclosed principles are illustrated by way of example, and not by way of limitation, in detail in the drawings, wherein:

FIG. 1 shows a fluid circuit configured to transfer heat with a circulating fluid.

FIG. 2 shows a top plan view of a fluid heat exchanger having a top cap cut away to facilitate viewing internal components;

FIG. 3 shows a sectional view along line I-I of FIG. 2;

FIG. 4 shows a sectional view along line II-II of FIG. 3;

FIG. 5 shows an exploded, perspective view of another fluid heat exchanger;

FIG. 6 shows a top plan view of the fluid heat exchanger shown in FIG. 5 assembled with its top cap removed;

FIG. 7 illustrates an exploded view of one embodiment of an integrated pump and heat exchanger assembly.

FIG. 8 illustrates an isometric view of an exploded subassembly of the integrated housing and pump impeller shown in FIG. 7.

FIG. 9 illustrates a partial cross-sectional, top plan view of the integrated housing shown in FIGS. 7 and 8.

FIG. 10 illustrates an isometric view from below of the integrated housing shown in FIGS. 7, 8 and 9.

FIG. 11 illustrates an exploded view of a subassembly comprising the heat sink, the integrated housing and the manifold insert shown in FIG. 7.

FIG. 12 illustrates a top plan view of the insert shown in FIGS. 7 and 11.

FIG. 13 illustrates an isometric view of a heat sink as shown in FIG. 7.

FIG. 13A is a photograph of a working example of the heat sink shown in FIG. 13.

FIG. 14 illustrates an isometric view of another embodiment of a heat sink as shown in FIG. 7.

FIG. 14A is a photograph of a working example of the heat sink shown in FIG. 14

FIG. 15 illustrates a typical cross-sectional view of a heat sink as shown in FIG. 7, taken along Section 15-15 in FIG. 13 or FIG. 14.

FIG. 16 illustrates an embodiment of a beveled fin configuration in a magnified view of the circled portion of a heat sink as shown in FIG. 15 and labeled “A”.

FIG. 17 illustrates an embodiment of a blunt fin configuration in a magnified view of the circled portion of a heat sink as shown in FIG. 15 and labeled “A”.

FIG. 18A illustrates cross-sectional view along Section 18-18 in FIG. 14 of a heat sink having a v-shaped groove in its fins. A plan view of a fin defining a v-shaped recess is shown in FIG. 18A.

FIG. 18B illustrates cross-sectional view along Section 18-18 in FIG. 14 of a heat sink having a generally parabolic groove in its fins. A plan view of a fin defining a generally parabolic recess is shown in FIG. 18B.

FIG. 19 illustrates a cross-sectional view of the heat sink shown in FIG. 18A with the manifold insert shown in FIG. 12 overlying the fins of the heat sink.

FIG. 19A illustrates a cross-sectional view of the heat sink shown in FIG 13 with the manifold insert shown in FIG. 12 overlying the fins of the heat sink.

FIG. 19B illustrates a cross-sectional view of the heat sink shown in FIG. 14 with the manifold insert shown in FIG. 12 overlying the fins of the heat sink.

DETAILED DESCRIPTION

The following describes various innovative principles related to heat exchange systems by way of reference to specific examples. However, one or more of the disclosed principles can be incorporated in various system configurations to achieve any of a variety of corresponding system characteristics. The detailed description set forth below in connection with the appended drawings is intended as a description of various embodiments and is not intended to represent the only embodiments contemplated by the inventor. The detailed description includes specific details for the purpose of providing a comprehensive understanding of the principles disclosed herein. However, it will be apparent to those skilled in the art after reviewing this disclosure that one or more of the claimed inventions may be practiced without one or more of the illustrated details.

Stated differently, systems described in relation to particular configurations, applications, or uses, are merely examples of systems incorporating one or more of the innovative principles disclosed herein and are used to illustrate one or more innovative aspects of the disclosed principles. Thus, heat exchange systems having attributes that

are different from those specific examples discussed herein can embody one or more of the innovative principles, and can be used in applications not described herein in detail, for example to transfer heat to or from components in a data center, laser components, light-emitting diodes, chemical reactions, photovoltaic cells, solar collectors, and a variety of other industrial, military and consumer devices now known or hereafter developed. Accordingly, such alternative embodiments also fall within the scope of this disclosure.

FLUID CIRCUIT

The schematic illustration in FIG. 1 shows several functional features common among disclosed fluid-based heat exchanger systems. For example, the fluid circuit 10 has a first heat exchanger 11 configured to absorb heat from a heat source (not shown in FIG. 1) and a second heat exchanger 12 configured to reject heat from the circuit 10. As indicated in FIG. 1, a working fluid, or coolant, can circulate between the heat exchangers 11, 12 to carry the energy absorbed in the first heat exchanger to the second heat exchanger 12. One or both of the heat exchangers 11, 12 can be a microchannel heat exchanger.

As used herein, "microchannel" means a fluid conduit, or channel, having at least one major dimension (e.g., a channel width) measuring less than about 1 mm, such as, for example, about 0.1 mm, or several tenths of millimeters.

As used herein, "fluidic" means of or pertaining to a fluid (e.g., a gas, a liquid, a mixture of a liquid phase and a gas phase, etc.). Thus, two regions that are "fluidicly coupled" are so coupled to each other as to permit a fluid to flow from one of the regions to the other region in response to a pressure gradient between the regions.

As used herein, the terms "working fluid" and "coolant" are interchangeable. Although many formulations of working fluids are possible, common formulations include distilled water, ethylene glycol, and mixtures thereof.

As used herein, the terms “heat sink” and “heat exchanger” are interchangeable and mean a device configured to transfer energy to or from a fluid through convection (i.e., a combination of conduction and advection) heat transfer.

Referring again to FIG. 1, the working fluid typically enters a first manifold 13 (sometimes after passing through an inlet plenum, which is omitted from FIG. 1 for ease of illustration). From the manifold 13, the fluid can be distributed among a plurality of fluid passages 14 configured to transfer heat from a heat-transfer surface, e.g., a wall in the heat exchanger 11, to the working fluid. In some embodiments, such as the examples described below, the fluid passages 14 are configured as microchannels and the walls are configured as extended heat-transfer surfaces, or fins.

During operation of the circuit 10, energy conducts (e.g., diffuses) from the walls of the first heat exchanger into adjacent fluid particles within the passages 14, and the adjacent fluid particles are swept away from the wall, or advected, carrying the energy absorbed from the walls. The swept-away particles are replaced by other, usually cooler fluid particles, which more readily absorb energy from the walls (e.g., by virtue of their usually lower temperature). Such a combination of conduction and advection (i.e., convection) provides an efficient approach for cooling devices having a relatively high heat flux, such as, for example, electronic devices.

After passing through the plurality of passages 14 in the first heat exchanger 11, the heated working fluid collects in an exhaust manifold 15 and passes to the second heat exchanger 12, carrying with it the energy absorbed from the first heat exchanger 11. As the heated fluid passes through the second heat exchanger 12, energy is rejected from the fluid (e.g., to another working fluid, such as, for example, the air or a building’s water

supply) through convection processes similar to those described above. From the second heat exchanger, the cooled working fluid passes through a pump 16 and back to the first heat exchanger 11.

The dashed box in FIG. 1 indicates that several functional components of the circuit 10 can be integrated into a single subassembly. As an example, the subassembly 20 includes the pump 16, the manifolds 13, 15 and the passages 14. An inlet 21 and an outlet 22 operatively couples the subassembly 20 to the second heat exchanger 12. A working embodiment of such a subassembly 20 is described below in connection with FIG. 7.

Each of the innovative features described herein can be incorporated, either singly or in combination, in connection with the first heat exchanger 11, the second heat exchanger 12, or both.

HEAT EXCHANGER EXAMPLE

With reference to FIGS. 2 to 4, a fluid heat exchanger 100 is shown. Fluid heat exchanger 100 includes a heat spreader plate 102, an arrangement of fluid microchannels 103 defined between walls 110, a fluid inlet passage 104, and a fluid outlet passage 106. A housing 109 operates with heat spreader plate 102 to form an outer limit of the heat sink and to define fluid flow passages 104, 106.

As shown in FIGS. 3 and 4, in use the heat exchanger 100 is coupled to a heat source 107, such as an electronic device, including, but not limited to a microchip or an integrated circuit. The heat exchanger may be thermally coupled to the heat source by a thermal interface material disposed therebetween, by coupling directly to the surface of the heat source, or by integrally forming the heat source and at least the heat spreader plate 102 of the fluid heat exchanger. The heat exchanger 100 may take various forms and shapes, but heat spreader plate 102 is formed to accept thermal energy from heat

source 107. Heat spreader plate 102 includes an intended heat generating component contact region 102b positioned in a known location thereon. In the illustrated embodiment, heat spreader plate 102 includes a protrusion at region 102b that controls the positioning of the heat spreader plate relative to the heat source, but such a protrusion need not be included. Heat spreader plate 102 may include a portion of more conductive material to facilitate and control heat transfer, if desired. In any event, heat spreader plate is formed to fit over and thermally communicate with a heat source in a region 102b, usually located centrally relative to the edges of the heat spreader plate.

Microchannels 103 are formed to accept and allow passage therethrough of the flow of heat exchanging fluid such that the fluid can move along heat spreader plate 102 and walls 110 and accept and dissipate heat energy from them. In the illustrated embodiment, microchannels 103 are defined by walls 110 that are thermally coupled to the heat spreader plate to accept thermal energy therefrom. For example, heat spreader plate 102 may include an inner facing, upper surface 102a and a plurality of microchannel walls 110 may extend upwardly therefrom, whereby the channel area, defined between upper surface 102a and the microchannel walls 110, channels or directs fluid to create a fluid flow path. The channel area may be open or filled with thermally conductive porous material such as metal or silicon foam, sintered metal, etc. Thermally conductive, porous materials allow flow through the channels but create a tortuous flow path.

Surface 102a and microchannel walls 110 allow the fluid to undergo exchange of thermal energy from the heat spreader plate to cool the heat source coupled to the heat spreader plate. The upper surface 102a and walls 110 have a high thermal conductivity to allow heat transfer from the heat source 107 to fluid passing through channels 103. The surfaces forming channels 103 may be smooth and solid, formed with a porous structure, such as of sintered metal and/or metal or silicon foam or roughened, for example, including troughs and/or crests designed to collect or repel fluid from a particular

location or to create selected fluid flow properties. Facing microchannel walls 110 may be configured in a parallel configuration, as shown, or may be formed otherwise, provided fluid can flow between the microchannel walls 110 along a fluid path. It will be apparent to one skilled in the art that the microchannel walls 110 may be alternatively configured in any other appropriate configuration depending on various factors of desired flow, thermal exchange, etc. For instance, grooves may be formed between sections of microchannel walls 110. Generally, microchannel walls 110 may desirably have dimensions and properties which seek to reduce or possibly minimize the pressure drop or differential of fluid flowing through the channels 103 defined therebetween.

The microchannel walls 110 may have a width dimension within the range of 20 microns to 1 millimeter and a height dimension within the range of 100 microns to five millimeters, depending on the power of the heat source 107, desired cooling effect, etc. The microchannel walls 110 may have a length dimension which ranges between 100 microns and several centimeters, depending on the dimensions of, and the heat flux density from, the heat source. In one embodiment, the walls 110 extend the full length (which may be a width) dimension of the heat spreader plate passing fully through region 102b. These are exemplary dimensions and, of course, other microchannel wall dimensions are possible. The microchannel walls 110 may be spaced apart by a separation dimension range of 20 microns to 1 millimeter, depending on the power of the heat source 107, although other separation dimensions are contemplated.

Other microporous channel configurations may be used alternatively to, or together with, microchannels, such as for example, a series of pillars, fins, or undulations, etc. which extend upwards from the heat spreader plate upper surface or tortuous channels as formed by a foam or sintered surface.

Fluid heat exchanger 100 further includes a fluid inlet passage 104, which in the illustrated embodiment includes a port 111 through the housing opening to a header 112 and thereafter a fluid inlet opening 114 to the microporous fluid channels 103.

FLUID DISTRIBUTION

The port and the header can be formed in various ways and configurations. For example, port 111 may be positioned on top, as shown, side or end regions of the heat exchanger, as desired. Port 111 and header 112 are generally of a larger cross sectional area than opening 114, so that a mass flow of fluid can be communicated substantially without restriction to opening 114.

Although only a single fluid inlet opening 114 is shown, there may be one or more fluid inlet openings providing communication from the header to the fluid microchannels 103.

Fluid inlet opening 114 may open to microchannels 103 opposite the heat spreader plate such that fluid passing through the opening may pass between walls 110 toward surface 102a, before being diverted along the axial length of the channels, which extend parallel to axis x. Since most installations will position the heat spreader plate as the lowermost, as determined by gravity, component of heat exchanger 100, the fluid inlet openings 114 can generally be described as being positioned above the microchannels 103 such that fluid may flow through opening 114 down into the channels in a direction orthogonal relative to the plane of surface 102a and towards surface 102a and then change direction to pass along the lengths of channels 103 substantially parallel to surface 102a and axis x. Such direction change is driven by impingement of fluid against surface 102a.

Fluid inlet opening 114 may be positioned adjacent to the known intended heat generating component contact region 102b since this region of the heat spreader plate

may be exposed to greater inputs of thermal energy than other regions on plate 102. Positioning the fluid inlet opening adjacent region 102b seeks to introduce fresh heat exchanging fluid first and directly to the hottest region of the heat exchanger. The position, arrangement and/or dimensions of opening 114 may be determined with consideration of the position of region 102b such that opening 114 may be placed adjacent, for example orthogonally opposite to, or according to the usual mounting configuration above, the intended heat generating component contact region 102b on the heat plate. The delivery of fresh fluid first to the region that is in direct communication with the heat generating component to be cooled seeks to create a uniform temperature at the contact region as well as areas in the heat spreader plate away from the contact region.

In the illustrated embodiment, opening 114 is positioned to have its geometric center aligned over the center, for example the geometric center, of region 102b. It is noted that it may facilitate construction and installation by intending, and possibly forming, the heat sink spreader plate to be installed with the heat generating component positioned on the plate substantially centrally, with respect to the plate's perimeter edges, and then opening 114 may be positioned also with its geometric center substantially centrally with respect to the perimeter edges of the heat spreader plate. In this way, the geometric center points of each of opening 114, the heat spreader plate and the heat generating component may all be substantially aligned, as at C.

Opening 114 may extend over any channel 103 through which it is desired that heat exchange fluid flows. Openings 114 may take various forms including, for example, various shapes, various widths, straight or curved edges (in plane or in section) to provide fluid flow features, open area, etc., as desired.

Heat exchanger 100 further includes a fluid outlet passage 106, which in the illustrated embodiment includes one or more fluid outlet openings 124 from the

microporous fluid channels 103, a header 126 and an outlet port 128 opening from the housing. Although two fluid outlet openings 124 are shown, there may be one or more fluid outlet openings providing communication to the header from the fluid channels 103.

The port and the header can be formed in various ways and configurations. For example, port 128 may be positioned on top, as shown, side or end regions of the heat exchanger, as desired.

Fluid outlet openings 124 may be positioned at the end of microchannels 103. Alternately or in addition, as shown, fluid outlet openings 124 may create an opening opposite heat spreader plate 102 such that fluid passing through the channels pass axially along the length of the channels between walls 110 and then changes direction to pass away from surface 102a out from between the walls 110 to exit through openings 124. Since most installations will position the heat spreader plate as the lowermost, as determined by gravity, component of heat exchanger 100, the fluid outlet openings 124 will generally be positioned above the microchannels 103 such that fluid may flow from the channels upwardly through openings 124.

Fluid outlet openings 124 may be spaced from fluid inlet openings 114 so that fluid is forced to pass through at least a portion of the length of channels 103 where heat exchange occurs before exiting the microchannels. Generally, fluid outlet openings 124 may be spaced from the known intended heat generating component contact region 102b.

In the illustrated embodiment, where heat exchanger 100 is intended to be mounted with heat source 107 generally centrally positioned relative to the perimeter edges of heat spreader plate 102, and thereby the ends 103a of channels, openings 124 may be positioned at or adjacent channel ends 103a.

At least one opening 124 extends over any channel 103 through which it is desired that heat exchange fluid flows. Openings 124 may take various forms including,

for example, various shapes, various widths, straight or curved edges (in plane or in section) to provide fluid flow features, open area, etc. as desired.

Fluid inlet opening 114 may open away from the ends of the microchannels, for example along a length of a microchannel between its ends. In this way, fluid is introduced to a middle region of a continuous channel 103 rather than fluid being introduced to one end of a channel and allowing it to flow the entire length of the channel. In the illustrated embodiment, heat exchanger 100 is intended to be mounted with heat source 107 generally centrally positioned relative to the perimeter edges of heat spreader plate 102. As such, in the illustrated embodiment, opening 114 is positioned generally centrally relative to the edges of the heat plate 102. Since the channels, in the illustrated embodiment extend substantially continuously along the length of the heat plate between opposing side perimeter edges thereof, opening 114 opens generally centrally between ends 103a of each channel. For example, opening 114 may be positioned in the middle 50% of the heat exchanger or possibly the middle 20% of the heat exchanger. The delivery of fresh fluid to the central region where the heat generating component is in direct communication with the heat spreader plate, first before passing through the remaining lengths of channels seeks to create a uniform temperature at region 102b as well as areas in the heat spreader plate adjacent to the intended mounting position. The introduction of fluid to a region along a middle region of the microchannels after which the flow splits into two sub flows to pass outwardly from the inlet towards a pair of outlets, each of which is positioned at the ends of the channels reduces the pressure drop of fluid passing along the channels over that pressure drop that would be created if the fluid passed along the entire length of each channel. Splitting the fluid flow to allow only approximately one half of the mass inlet flow to pass along any particular region of the microchannels creates less back pressure and less flow resistance, allows faster fluid flow through the channels and lessens the pump force required to move the fluid through the heat exchanger.

In use, heat spreader plate 102 is positioned in thermal communication with heat source 107 at region 102b. Heat generated by heat source 107 is conducted up through heat spreader plate 102 to surface 102a and walls 110. Heat exchanging fluid, as shown by arrows F, enters the fluid heat exchanger through port 111, passes into the header 112 and through opening 114. The heat exchanging fluid then passes down between walls 110 into channels 103, where the fluid accepts thermal energy from the walls 110 and surface 102a. The heat exchanging fluid, after passing down into the channels, then impinges against surface 102a to be diverted toward ends 103a of the channels toward outlet openings 124. In so doing, in the illustrated embodiment, the fluid is generally split into two subflows moving away from each other and away from inlet 114 toward openings 124 at the ends of the microchannels. Fluid passing through channels becomes heated, especially when passing over the region in direct contact with the heat source, such as, in the illustrated embodiment, the central region of the heat spreader plate. Heated fluid passes out of openings 124, into header and thereafter through port 128. The heated fluid will circulate through a heat sink where its thermal energy is unloaded before circulating back to port 111.

The individual and relative positioning and sizing of openings 114 and 124 may allow fluid to circulate through the heat exchanging channels 103 while reducing the pressure drop generated in fluid passing through heat exchanger 100, when compared to other positionings and sizings. In the illustrated embodiment, for example, the central region 124a of outlet openings 124 are scalloped to offer an enlarged outlet region from the centrally located channels, relative to those on the edges. This shaping provides that the outlet openings from some centrally positioned channels 103, relative to the sides of the heat exchanger, are larger than the outlet openings from other channels closer to the edges. This provides that fluid flowing through the more centrally located channels encounters less resistance to flow therethrough, again facilitating flow past the central mounting region 102b on heat spreader plate 102.

A seal 130 separates fluid inlet passage 104 from fluid outlet passage 106 so that fluid must pass through the microporous channels 103 past heat spreader plate surface 102a.

METHODS OF MANUFACTURE

With reference to FIGS. 5 and 6, a useful method for manufacturing a fluid heat exchanger is described. A heat spreader plate 202 may be provided which has heat conductive properties through its thickness at least about a central region thereof.

Microchannels may be formed on the surface of the heat spreader plate, as by adding walls or forming walls by building up or removing materials from the surface of the heat plate. In one embodiment, skiving is used to form walls 210.

A plate 240 may be installed over the walls 210 to close off the channels across the upper limits of walls 210. Plate 240 has portions removed to create inlet and outlet openings 214 and 224, respectively, in the final heat exchanger. Tabs 242 may be used to assist with the positioning and installation of plate 240, wherein tabs 242 are bent down over the two outermost walls.

Seal 230 may be installed as a portion of plate 240 or separately.

After plate 240 and seal 230 are positioned, a top cap 244 can be installed over the assembly. Top cap 244 can include side walls that extend down to a position adjacent heat spreader plate. The parts may be connected during assembly thereof or afterward by overall fusing techniques. In so doing, the parts are connected so that short circuiting from inlet passage to outlet passage is substantially avoided, setting up the fluid circuit as described herein above wherein the fluid flows from opening 214 to openings 224 through the channels defined between walls 210.

SYSTEM INTEGRATION

Referring now to FIG. 7, a working example of an integrated subassembly 20 (FIG. 1) is described. The illustrated subassembly 300 comprises a pump 310 and a heat exchanger 320, as well as housing 330 with integrated fluid conduits extending therebetween. The subassembly 300 is but one example of an approach for integrating several elements of the fluid circuit 10 shown in FIG. 1 (e.g., the pump 16 and the first heat exchanger 11, including the inlet manifold 13, the fluid passages 14, the exhaust manifold 15) into a single element while retaining the several elements' respective functions. The housing 330 is configured to convey a working fluid from an inlet port 331 to a pump volute 311, from the pump volute to an inlet 321 (FIG. 11) to the heat exchanger 320, and from an outlet 322 (FIG. 11) of the heat exchanger to an outlet port 332.

The pump impeller 312 can be received in the pump volute 311. The impeller can be driven in rotation by an electric motor 313 in a conventional manner. A cap 301 can overlie the motor 313 and fasten to the housing 330 to provide the subassembly 300 with a finished appearance suitable for use with, for example, consumer electronics.

The side 333 of the housing 330 positioned opposite the pump volute 311 can receive an insert 334 and the heat exchanger 320. A seal (e.g., an O-ring) 323 can be positioned between the housing 330 and the heat exchanger 320 to reduce and/or eliminate leakage of the working fluid from the interface between the heat exchanger 320 and the housing 330.

The heat exchanger 320 defines a lower-most face of the assembly 300, as well as a surface configured to thermally couple to an integrated circuit (IC) package (not shown). A retention mechanism 302 can mechanically couple the assembly to a substrate, such as a printed circuit board to which the IC package is assembled.

As with the subassembly 20 shown in FIG. 1, a fluid conduit can fluidicly couple an outlet port of a remotely positioned heat exchanger to the inlet port 331 of the housing 330. As well, a fluid conduit can fluidicly couple the outlet port 332 of the housing 330 to an inlet port of the remotely positioned heat exchanger. In a cooling application, the respective fluid conduits convey relatively higher-temperature fluid from the outlet port 332 to the remote heat exchanger and from relatively lower-temperature fluid from the remote heat exchanger to the inlet port 331.

INTEGRATED HOUSING

An embodiment of a unitary housing 330 is now described by way of reference to FIGS. 7, 8, 9, 10 and 11. The illustrated housing 330 has a first side 340, a second side 333 positioned opposite the first side, and a substantially continuous perimeter wall 348 extending between the first side and the second side. A floor, or lower wall, 341 generally separates the first side from the second side. The opposed first side 340 and second side 333 define respective recessed features that, when combined with corresponding components, define integrated fluid conduits and chambers operable to convey a working fluid within a small form factor (e.g., within a volume having a maximum vertical dimension of ____ inches).

For example, the housing has an inlet port 331, a pump volute 311, an inlet plenum 335 (FIG. 10), an inlet manifold portion 336 corresponding to the inlet plenum, an exhaust manifold portion 337, an exhaust (or outlet) plenum 338 corresponding to the exhaust manifold portion, and an outlet port 332 fluidicly coupled with each other.

FIGS. 8 and 9 show that the perimeter wall can define a recessed inlet port 331. The first side 340 of the housing 330 defines a substantially cylindrically-shaped recess forming the pump volute 311, and a floor of the recessed volute 311 is defined by a substantially circular lower wall 341. An aperture 342 in the lower wall forms an inlet to the pump volute 311, and an inlet passage 343 extends between the inlet port 331 and the

inlet 342 to the pump volute 311, fluidicly coupling the pump volute and the inlet port to each other.

The opposite (e.g., a second) side 333 of the housing 330 defines a second recessed region 350 defining the inlet plenum 335 and the inlet manifold region 336. An opening 344 extends through a common wall 345 separating the inlet plenum 335 from the pump volute 311, fluidicly coupling the pump volute and the first plenum with each other. In some embodiments, the opening 344 extends generally tangentially of the cylindrically-shaped pump volute 311.

A charging port 349 can extend through the perimeter wall 348 and into the inlet plenum 335, allowing an assembled system to be charged with a working fluid after assembly. After charging, a plug (not shown) can be inserted into the charging port 349 to seal it.

As shown in FIG. 10, a depth of the inlet manifold 3336 can taper from a relatively deeper region adjacent the inlet plenum 335 to a relatively shallower region spaced from the inlet plenum. As described more fully below, a manifold insert 334 overlies the sloped recess of the manifold region 336, forming an inlet manifold having a tapering cross-sectional area along a flow direction. The tapered manifold can distribute a substantially even mass-flow rate among a plurality of channels in the heat sink.

The second side 333 of the housing 330 can define a third recessed region 351 defining respective portions of an exhaust manifold 337 (FIG. 11). As described more fully below, the third recessed region 351 can overlie a portion of the heat exchanger 320 and thereby receive a discharged working fluid from the microchannels.

A fourth recessed region 352 can define, at least in part, an outlet plenum 338. The third recess 351 and the fourth recess 352 can be fluidicly coupled to each other and

separated by a wall 346 from the second recessed region350. An opening 347 (FIG. 9) extends between the outlet plenum 338 and the outlet port 332.

A manifold housing as described above can have a unitary construction formed using, for example, an injection molding technique, a machining technique, or other suitable process now known or hereafter developed. Also, any suitable material can be used in the construction of the housing, provided that the material is compatible with other components of the subassembly 300 and the working fluid.

Although the housing described above has a unitary construction, other embodiments of the housing 330 can comprise an assembly of subcomponents. Nonetheless, a unitary construction typically has fewer separable couplings from which a working fluid can leak.

MANIFOLD INSERT

As noted above and shown in FIGS. 7 and 11, an insert 334 can be positioned between the heat exchanger 320 and the housing 330. Additionally, the insert 334 can have a contour generally corresponding to the configuration of one or more of the recessed regions 350, 351, 352 in the second side 333 of the housing 330. When the insert 334 is mated with the housing 330, the recessed regions 350, 351 and 352, in combination with the contoured insert 334, define several conduits that fluidicly couple the heat exchanger 320 with the pump volute 311 and the outlet port 332.

For example, the insert 334 can define an opening extending through the body 360 and generally overlying the tapered manifold portion 336 defined by the housing 330. The opening can include a recessed region 365 and an aperture 361. The recessed region 365 and the tapered recess 336 in the housing together define a chamber of the inlet manifold. As described below, the manifold can distribute working fluid among the several microchannels within the heat sink.

The body 360 of the insert 334 can matingly engage with one or more features of the housing 330. For example, the body 360 can define a plurality of spaced apart members 362a, b, c, d and a trough-shaped recess 363 extending transversely relative to the aperture 361. The trough-shaped recess 363 can extend between the members 362a, c and between the members 362b, d. When the insert 334 is assembled with the housing 330, the members 362a, b, c, d are positioned in corresponding portions of the second recessed region 351, and a corresponding ridge 339 (FIG. 10) is positioned within the trough-shaped recess 363. By straddling features defined by the housing, the insert is configured to align the aperture 361 with the tapered manifold region 336 in a generally repeatable fashion.

The insert body 360 also defines a contoured tab 364 configured to overly the recessed inlet plenum 335. In addition, a shoulder 366 within the second recessed region 365 of the insert urges against the wall 346 (FIG. 10), providing a seal separating the inlet manifold from the exhaust manifold and outlet plenum.

In a working embodiment, the recessed region 365 is tapered, having at least one cross-sectional dimension that diminishes with increasing depth of the recess. As explained more fully below, the recess 365 and the aperture 361 in the insert can generally overlie a groove 325 (FIG. 19) in the heat sink fins. In some instances, a slope of a wall defining the tapered recess 365 adjacent the aperture 361 can be matched to a slope of the recessed groove adjacent a distal end of the heat sink fins, providing a relatively smooth and continuous flow transition.

The insert can have a pair of generally conformable, flat surfaces 367 laterally flanking the aperture 367. The surfaces 367 can generally overlie respective portions of the heat exchanger 320 (e.g., the distal ends 401 of heat sink fins 400 (FIG. 19)) and define an upper flow boundary of the microchannels extending between adjacent fins, similar to the plate 240 shown in FIGS. 5 and 6. The conformable surfaces 367 can urge

against the respective distal ends, conforming to variations in height among the plurality of fins, and within a given fin (e.g., a fin having a non-linear longitudinal contour). The conformable surfaces 367 can reduce or eliminate the need for secondary machining operations used to make the respective distal ends of the fins generally coplanar and compatible with, for example, the plate 240.

The insert body 360 can be formed using, for example, an injection molding technique, a machining technique, or other suitable process now known or hereafter developed. In a working embodiment, the body 360 is formed of a compliant polymeric material that generally conforms to and seals against adjacent surfaces. Any suitable material can be used to form the insert body 360, provided that the selected material is compatible with other components of the subassembly 300 and the selected working fluid.

<u>FLOW DISTRIBUTION</u>

Flow of a working fluid through the integrated assembly 300 is now described. From a remotely positioned heat exchanger (not shown), a working fluid passes into the inlet port 331 and into the channel 343 extending between the inlet port and the inlet 342 to the pump volute 311. A floor 341 of the pump volute defines a wall separating the channel 343 from the pump volute. From the channel 343, the working fluid passes through the aperture 342 and into the volute 311. An impeller 312 positioned in the pump volute 311 rotates and increases a pressure head in the working fluid before the fluid passes from the pump volute through the opening 344 and into the inlet plenum 335.

As indicated by the arrows in FIG. 10, the working fluid can pass from the inlet plenum 335 and into a chamber formed between the second recessed region 365 in the insert 334 and the inlet manifold portion 336 of the housing. From the chamber, the working fluid passes through the aperture 361.

As described above in connection with FIGS. 2, 3 and 4, the heat exchanger shown in FIGS. 7, 11, 13 and 14 can comprise a heat transfer region 324 defining a plurality of microchannel passages. The aperture 361 can overlie the heat transfer region 324, and the flow of working fluid can be distributed among the plurality of microchannel passages in the heat sink. As with the assembly shown in FIGS. 5 and 6, a flow of working fluid within the microchannel can generally be an impinging flow divided into a first portion and a second portion flowing outwardly from the impingement region in generally opposite directions.

In the illustrated assembly 300 (FIG. 7), the insert 334 (e.g., the members 362 a,b,c,d) partially occupies the third recessed region 351, leaving a pair of opposed portions of the region unfilled and defining opposed exhaust manifold portions 337 overlying end regions of the microchannels and flanking the central region adjacent the aperture 361 (FIG. 11). The outwardly directed flow of coolant can exhaust from the microchannel passages into a respective one of the exhaust manifold portions 337. From the manifold portions 337, the working fluid passes into the outlet plenum 338 (FIG. 11), and through the conduit 347 to the outlet port 332.

ADDITIONAL HEAT EXCHANGER CONFIGURATIONS

Additional heat sink embodiments are described with reference to FIGS. 13, 14, 15, 16, 17, 18A and 18B. As with the heat sink illustrated in FIG. 2 through FIG. 6, the heat sinks 320, 324’ shown in FIGS. 13 and 14 define respective heat transfer regions 324, 324’ having a plurality of juxtaposed fins 400, 400’ defining a corresponding plurality of microchannels 404, 404’ between adjacent fins.

Each of the fins 400, 400’ extend from a heat spreader, or base, 326, to a respective distal end 401, 401’. Flanking grooves 322, 322’ (FIGS. 13 and 14) can extend orthogonally relative to opposed outer ends of the microchannels 404, 404’, forming a portion of the exhaust manifold. When incorporated in the assembly 300, the grooves 322, 322’ are generally positioned adjacent opposed exhaust manifold portions 337.

FIG. 15 shows a typical cross-sectional view of the heat sinks 320, 320’ along section line 15-15 (FIG. 13) or 15’-15’ (FIG. 14), respectively. FIGS. 16 and 17 show alternative fin configurations from the circled portion “A” of a typical heat transfer region shown in cross-section in FIG. 15.

The distal ends of the fins can have a variety of configurations; two alternatives are shown in FIGS. 16 and 17. For example, the blunt distal ends 401’ are shown as being relatively flat and generally coplanar. Alternatively, the distal ends 401 are shown as being beveled, giving each fin 400a a comparatively shorter face 402 and a comparatively taller face 403, with a relatively sharp apex 405 positioned therebetween.

It is believed that the relatively sharp apex 405 formed by the beveled distal ends 401 can improve transition of a flow direction from being generally parallel to the base 326 (indicated by arrows 406 in FIG. 16) to a direction being generally orthogonal to the base 326. Accordingly, it is surmised that fins 400 having sharp apices 405 formed by

beveled distal ends can reduce head losses in the working fluid as it passes from the insert manifold to the microchannels as compared to, for example, fins 400' having generally blunt distal ends 401'. It is believed that positioning the relatively taller face 403 of a given fin upstream of the relatively shorter face 402 of the same fin, as shown in FIG. 16, provides a relatively larger reduction in head loss than if the flow approaches the beveled fin from an opposite direction.

The beveled distal ends 401 can be formed using any suitable technique for beveling thin walls. For example, such bevels can be produced when forming the fins 400 using a skiving technique. Other, e.g, proprietary, techniques can be used to form the bevels. For example, it is believed that the fin-forming technique employed by Wolverine Tube, Inc. can be used to produce microchannel heat sinks having beveled fins. However, it is also believed that the respective distal ends of such “raw” fins may not be coplanar. By incorporating the compliant insert 334, secondary machining operations that would tend to dull the sharp apices 405 can be eliminated to reduce heat losses in the coolant, while still reducing or eliminating leakage between adjacent microchannels that might otherwise occur from using “raw” fins due to gaps that would be formed between the fins and, e.g., a generally planar plate 240.

As shown in FIG. 14, a transverse groove 325 can extend transversely relative to the fins 400. As noted above, the aperture 361 in the manifold insert 334 can generally overlie the groove 325, defining a flow transition that hydraulically couples in parallel each of the microchannels 404 to at least one other of the microchannels.

FIG. 19 shows a cross-sectional view of one example of such a flow transition. The recessed region 365 defined by the insert body 360 and the recessed groove 325 together define a substantially larger effective characteristic length than the aperture 361 does alone. For example, the recessed region 365, the aperture 361 and the groove 325 can together define a flow transition having an effective characteristic length between

about ____% and about ____% greater than the corresponding effective characteristic length of the aperture 361 alone.

Increasing the effective characteristic length of the transition from the inlet manifold to the microchannels of the heat sink 320 reduces pressure losses and improves local heat transfer rates from the fins compared to a case where the aperture 361 overlies an array of blunt fins (e.g., FIG. 18B). The combination of the tapered recess and the heat sink groove 325 allows the working fluid to penetrate relatively deeper in the microchannels in a region adjacent the aperture than the fluid otherwise would in the absence of the groove (e.g., in the case of an array of blunt fins).

The groove 325 can be formed by defining a respective recess in each of the plurality of fins 400. The plurality of recessed regions can be so juxtaposed as to define the groove 325.

In FIGS. 18A and 18B, the lowermost extent of each recessed groove 325a, 325b is spaced a distance h_1 from the heat spreader 326. In other embodiments, the lowermost extent of the recessed groove 325 is substantially coextensive with the heat spreader 326 (i.e., $h_1 \leq 0$) . In some embodiments, a ratio of a representative height h_2 of the fins to the distance h_1 can be between about ____ and about ____, such as, for example, between about ___ and about ____.

Although a v-shaped notch is shown in FIG. 18A, and a generally parabolic recess is shown in FIG. 18B, other recessed groove configurations are possible. For example, the groove can have a generally hyperbolic cross-sectional shape, or a cross-section with at least one substantially straight edge (e.g., an L-shaped recess). As noted above, a slope of the groove 325 adjacent the manifold body can be substantially continuous with a slope of a wall defining the recessed region 365 in the manifold body 360 adjacent the groove, when the integrated assembly 300 is assembled. Such a continuous slope can

provide generally lower head losses through the transition than in transitions having a discontinuity in wall slope (e.g., between the recess in the insert and the groove).

<u>OTHER EXEMPLARY EMBODIMENTS</u>

The examples described above generally concern fluidic heat transfer systems configured to cool one or more electronic components, such as integrated circuits. Nonetheless, other applications for disclosed heat transfer systems are contemplated, together with any attendant changes in configuration of the disclosed apparatus. Incorporating the principles disclosed herein, it is possible to provide a wide variety of systems configured to transfer heat using a fluid circuit. For example, disclosed systems can be used to transfer heat to or from components in a data center, laser components, light-emitting diodes, chemical reactions, photovoltaic cells, solar collectors, and a variety of other industrial, military and consumer devices now known and hereafter developed.

Directions and references (*e.g.*, up, down, top, bottom, left, right, rearward, forward, etc.) may be used to facilitate discussion of the drawings but are not intended to be limiting. For example, certain terms may be used such as "up," "down,", "upper," "lower," "horizontal," "vertical," "left," "right," and the like. Such terms are used, where applicable, to provide some clarity of description when dealing with relative relationships, particularly with respect to the illustrated embodiments. Such terms are not, however, intended to imply absolute relationships, positions, and/or orientations. For example, with respect to an object, an "upper" surface can become a "lower" surface simply by turning the object over. Nevertheless, it is still the same surface and the object remains the same. As used herein, “and/or” means “and” or "or", as well as “and” and “or.” Moreover, all patent and non-patent literature cited herein is hereby incorporated by references in its entirety for all purposes.

The principles described above in connection with any particular example can be combined with the principles described in connection with any one or more of the other examples. Accordingly, this detailed description shall not be construed in a limiting sense, and following a review of this disclosure, those of ordinary skill in the art will appreciate the wide variety of fluid heat exchange systems that can be devised using the various concepts described herein. Moreover, those of ordinary skill in the art will appreciate that the exemplary embodiments disclosed herein can be adapted to various configurations without departing from the disclosed principles.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the disclosed innovations. Various modifications to those embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of this disclosure. Thus, the claimed inventions are not intended to be limited to the embodiments shown herein, but are to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular, such as by use of the article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure that are know or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 USC 112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or "step for".

Thus, in view of the many possible embodiments to which the disclosed principles can be applied, it should be recognized that the above-described embodiments are only examples and should not be taken as limiting in scope. I therefore reserve all

rights to the subject matter disclosed herein, including the right to claim all that comes within the scope and spirit of the following paragraphs, as well as all aspects of any innovation shown or described herein.

CURRENTLY CLAIMED INVENTIONS:

1. A heat exchange system comprising:

a heat sink having a plurality of juxtaposed fins defining a corresponding plurality of microchannels positioned between adjacent fins, wherein a recessed groove in the heat sink extends in a transverse direction relative to the juxtaposed fins;

a manifold body at least partially defining an opening generally overlying the groove.

2. The heat exchange system of claim 1, wherein the manifold body and the groove together define a portion of an inlet manifold configured to hydraulically couple in parallel each of the microchannels to at least one other of the microchannels.

3. The heat exchange system of claim 1, wherein the heat sink comprises a base, each of the fins extends from the base and defines a corresponding distal edge spaced from the base, and the groove is recessed from the respective plurality of distal edges.

4. The heat exchange system of claim 3, wherein a lowermost extent of the recessed groove is spaced from the base.

5. The heat exchange system of claim 3, wherein a lowermost extent of the recessed groove is substantially coextensive with the base.

6. The heat exchange system of claim 3, wherein the base and the fins form a unitary construction.

7. The heat exchange system of claim 3, wherein each of the respective distal edges defines a corresponding recessed portion, thereby defining the recessed groove.

8. The heat exchange system of claim 1, wherein the heat sink further comprises a base, wherein the fins extend from the base, and the groove comprises a first groove and a second groove being recessed in the base and positioned in a flanking relationship with the fins and microchannels so as to at least partially define an exhaust manifold region.

9. The heat exchange system of claim 8, wherein the groove further comprises a third groove, wherein each of the fins defines a corresponding distal edge spaced from the base, and the wherein the third groove is recessed from the respective plurality of distal edges.

10. The heat exchange system of claim 9, wherein the base and the fins form a unitary construction.

11. The heat exchange system of claim 9, wherein each of the respective distal edges defines a corresponding recessed portion, thereby defining the third groove.

12. The heat exchange system of claim 1, wherein a cross-sectional profile of the recessed groove comprises a selected one or more of the group consisting of a square groove, a v-shaped groove, a semi-circular groove, a parabolic groove, a hyperbolic groove, and a groove having at least one substantially straight edge.

13. The heat exchange system of claim 7, wherein a cross-sectional profile of each respective recessed portion comprises a selected one or more of the group consisting of a square groove, a v-shaped groove, a semi-circular groove, a parabolic groove, a hyperbolic groove, and a groove having at least one substantially straight edge.

14. The heat exchange system of claim 3, wherein a ratio of a representative height of the plurality of fins to a representative depth of the groove is between about ____ and about _____.

15. The heat exchange system of claim 14, wherein the ratio of the representative height to the representative depth is between about ____ and about _____.

16. The heat exchange system of claim 3, wherein the opening in the manifold body has a recessed region and an aperture extending from the recessed region through the manifold body.

17. The heat exchange system of claim 16, wherein the recessed region in the manifold body is a tapered recessed region having at least one cross-sectional dimension that diminishes with increasing depth of the recessed region.

18. The heat exchange system of claim 16, wherein a contour of the groove adjacent the distal edges of the fins is substantially continuous with a contour of the recessed region in the manifold body.

19. The heat exchange system of claim 16, wherein the recessed region, the aperture and the groove together define a flow transition having an effective characteristic length between about ____% and about ____% greater than a corresponding effective characteristic length of the aperture.

20. The heat exchange system of claim 2, wherein the inlet manifold is configured to direct a flow of a fluid to each of the microchannels in a transverse direction relative to an axis extending longitudinally of the respective microchannels.

21. The heat exchange system of claim 1, wherein each of the fins in the plurality of fins defines a corresponding beveled distal edge.

22. The heat exchange system of claim 2, further comprising a housing body defining an inlet manifold recess, wherein the opening in the manifold body comprises a recessed region and an aperture extending through the manifold body, wherein the recessed region in the manifold body and the inlet manifold recess are together configured to direct a fluid flow in a direction generally transverse to the fins.

23. The heat exchange system of claim 22, wherein the inlet manifold is configured to transition the flow direction from being generally transverse to the fins to a flow direction being generally parallel to the fins.

24. The heat exchange system of claim 23, wherein each of the fins in the plurality of fins defines a corresponding beveled distal edge.

25. The heat exchange system of claim 22, wherein the housing body comprises a unitary construction defining a first side, wherein a portion of an inlet plenum and the inlet manifold recess are respectively recessed from the first side, wherein the housing body defines a second side positioned opposite the first side, and a recess from the second side defines a pump volute, wherein the portion of the inlet plenum is positioned adjacent the pump volute.

26. The heat exchange system of claim 25, wherein the recess defining the pump volute is a substantially cylindrically-shaped recess having a longitudinal axis extending substantially perpendicularly to the second side, and wherein the housing body defines an opening extending generally tangentially of the cylindrically-shaped recess and hydraulically coupling the pump volute to the inlet plenum.

27. The heat exchange system of claim 22, wherein the housing body defines a second recessed region positioned adjacent the inlet manifold recess and a wall separating the second recessed region from the inlet manifold recess, wherein the manifold body is configured to straddle the inlet manifold recess and matingly engage the housing body such that the manifold body so occupies a portion of the second recessed region as to partially define an exhaust manifold region that generally overlies a corresponding portion of each of the microchannels, wherein the respective portions of the plurality of microchannels are spaced from the opening in the manifold body.

28. The heat exchange system of claim 27, wherein the exhaust manifold region overlies the groove.

29. The heat exchange system of claim 27, wherein the groove comprises an inlet groove and an exhaust groove, and wherein the opening in the manifold body generally overlies the inlet groove and the exhaust manifold region overlies the exhaust groove.

30. A heat exchange system comprising:

a heat sink having a plurality of juxtaposed fins defining a corresponding plurality of microchannels positioned between adjacent fins, wherein each of the fins defines a respective beveled distal edge; and

a manifold body overlying at least a portion of each of the beveled distal edges and defining an opening configured to direct a fluid flow into the microchannels in a direction generally transverse to an axis extending longitudinally of the microchannels.

31. The heat exchange system of claim 30, wherein the heat sink comprises a base, each of the fins extends from the base and each corresponding beveled distal edge is spaced from the base.

32. The heat exchange system of claim 31, wherein the base and the fins form a unitary construction.

33. The heat exchange system of claim 31, wherein a distance between a respective beveled distal edge and the base defines a height of the respective fin, wherein each respective fin defines a first end and an opposed second end and extends longitudinally in a spanwise direction relative to the base between the first end and the opposed second end, wherein the fin height of one or more of the plurality of fins varies along the spanwise direction.

34. The heat exchange system of claim 33, wherein the manifold body comprises a compliant portion urging against a corresponding portion of each of the distal edges.

35. The heat exchange system of claim 34, wherein the variation in fin height along the spanwise direction defines a non-linear contour of the respective distal edge, wherein the compliant portion of the manifold body generally conforms to the non-linear contour.

36. The heat exchange system of claim 30, wherein a recessed groove extends transversely relative to the fins.

37. The heat exchange system of claim 36, wherein the heat sink further comprises a base, wherein the fins extend from the base, and the groove comprises a first groove and a second groove being recessed in the base and positioned in a flanking relationship with the fins and microchannels so as to at least partially define an exhaust manifold region.

38. The heat exchange system of claim 36, wherein each of the respective distal edges defines a corresponding recessed portion, thereby defining the recessed groove, and wherein the opening generally overlies the groove.

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39. The heat exchange system of claim 30, wherein a ratio of a representative height of the plurality of fins to a representative depth of the groove is between about ____ and about _____.

40. The heat exchange system of claim 39, wherein the ratio of the representative height to the representative depth is between about ____ and about _____.

41. The heat exchange system of claim 36, wherein the opening in the manifold body has a recessed region and an aperture extending from the recessed region through the manifold body, wherein the recessed region, the aperture and the groove together define a flow transition having an effective characteristic length between about ____% and about ____% greater than a corresponding effective characteristic length of the aperture.

42. The heat exchange system of claim 30, further comprising a housing body defining a first side and a second side opposite the first side, wherein the body defines a portion of an inlet plenum being recessed from the first side and a portion of an inlet manifold being recessed from the first side, wherein the body further defines a pump volute recessed from the second side, wherein the portion of the inlet plenum is positioned adjacent the pump volute.

43. The heat exchange system of claim 42, wherein the recess defining the pump volute is a substantially cylindrically-shaped recess having a longitudinal axis

extending substantially perpendicularly to the second side, and a wherein the body defines an opening extending generally tangentially of the cylindrically-shaped recess and hydraulically coupling the pump volute to the portion of the inlet plenum.

44. The heat exchange system of claim 42, wherein the body defines a third recessed region positioned adjacent the portion of the inlet manifold, and a wall separating the third recessed region from the portion of the inlet manifold, wherein the manifold body is configured to straddle the portion of the inlet manifold and matingly engage the body such that the manifold body so occupies a portion of the third recessed region as to partially define an exhaust manifold region that generally overlies a corresponding portion of each of the microchannels, wherein the respective portions of the plurality of microchannels are spaced from the opening in the manifold body.

45. A unitary construct comprising a first side, a second side positioned opposite the first side, and a substantially continuous perimeter wall extending between the first side and the second side, and a floor generally separating the first side from the second side, wherein the first side defines a substantially cylindrical recessed pump volute and the second side defines an inlet plenum recess positioned radially outward of the pump volute.

46. The unitary construct of claim 45, further defining an aperture extending between the pump volute and the inlet plenum recess.

47. The unitary construct of claim 45, wherein the perimeter wall at least partially defines a perimeter recess and an aperture extends between the perimeter recess and the pump volute.

48. The unitary construct of claim 47, wherein the floor defines a portion of the perimeter recess and the floor defines the aperture extending between the perimeter recess and the pump volute.

49. The unitary construct of claim 45, wherein the perimeter wall defines a perimeter recess, the second side of the construct further defines a recessed exhaust region, and an aperture extends between the perimeter recess and the exhaust region.

50. A heat exchange system comprising:

a heat exchanger comprising a base, and a plurality of juxtaposed fins extending from the base and defining a corresponding plurality of microchannels positioned between adjacent fins, wherein the base of the heat exchanger defines an exhaust manifold groove extending transversely of the fins;

a unitary housing body having opposed first and second sides separated by a floor and defining an inlet port, a pump volute recess, an inlet plenum recess, an inlet manifold recess positioned adjacent to the inlet plenum recess, an exhaust manifold recess, an exhaust plenum recess positioned adjacent to the exhaust manifold recess, and an outlet port, wherein the first side of the housing defines the pump-volute recess, and an aperture extending through the wall fluidicly couples the inlet port to the pump-volute

recess, defining an inlet to the pump-volute recess, wherein the second side of the housing defines the respective inlet plenum recess, inlet manifold recess, and exhaust manifold recess, wherein an aperture extending generally tangentially of the pump-volute recess fluidicly couples the pump-volute recess and the inlet plenum recess, wherein a depth of the inlet-manifold recess tapers from a relatively deeper region adjacent the inlet plenum recess to a relatively shallower region spaced from the inlet plenum recess, wherein the second side of the housing further defines a wall separating the inlet manifold recess from the exhaust manifold recess, and wherein the exhaust manifold recess is positioned adjacent the exhaust plenum recess, wherein an aperture extends between the exhaust plenum recess and the outlet port; and

an insert having a compliant body and being configured to matingly engage the second side of the housing and to straddle the inlet manifold recess, wherein the insert defines a recessed opening having a taper from a relatively larger cross-sectional area to a relatively smaller cross-sectional area, wherein the recessed opening generally overlies the inlet manifold recess to partially define an inlet manifold to the heat exchanger, wherein the recessed opening extends transversely relative to the juxtaposed fins and corresponding microchannels such that each of the microchannels is fluidicly coupled in parallel to at least one other of the microchannels, wherein each of the plurality of fins defines a respective distal end spaced from the base and at least a portion of the compliant body overlies and urges against the plurality of respective distal ends forming a microchannel boundary positioned opposite the base, wherein each of the plurality of juxtaposed fins defines a respective recessed region adjacent the respective distal end, forming a groove extending transversely relative to the juxtaposed fins and being generally aligned with the opening in the insert to partially define a portion of the inlet manifold to the microchannels, wherein the outlet manifold recess in the housing so overlies a portion of the respective distal ends of the fins and the exhaust manifold groove in the base as to define a flow transition between the microchannels and the outlet

plenum recess, wherein one or more of the plurality of fins defines a respective beveled distal end such that each of the one or more of the plurality of fins has a relatively taller face and a relatively shorter face, wherein each relatively taller face is positioned closer to the inlet plenum than the corresponding relatively shorter face.

ABSTRACT

A heat sink can have a plurality of juxtaposed fins defining a corresponding plurality of microchannels. A recessed groove can extend transversely relative to the fins. A manifold body can at least partially define an opening generally overlying the groove. Each of the fins can define a respective beveled distal edge. The manifold body can overlie the beveled edges and define an opening configured to direct a fluid into the microchannels. A unitary construct can have a first side, a second side positioned opposite the first side, and a substantially continuous perimeter wall extending between the first side and the second side. A floor can generally separate the first side from the second side. The first side can define a substantially cylindrical recessed pump volute and the second side can define an inlet plenum recess positioned radially outward of the pump volute. A heat exchange system can include such components.

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (11-08)
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Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Geoff	Sean	Lyon	Calgary	AB	CA

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Title of Invention	FLUID HEAT EXCHANGE SYSTEMS
Attorney Docket Number (if applicable)	COOL-2.001.PR2

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	○ Firm or Individual Name
Customer Number	22874

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

◉ No.

○ Yes, the name of the U.S. Government agency and the Government contract number are:

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

Entity Status

Applicant claims small entity status under 37 CFR 1.27

○ Yes, applicant qualifies for small entity status under 37 CFR 1.27

◉ No

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Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Lloyd L. Pollard II/			Date (YYYY-MM-DD)	2011-07-27
First Name	Lloyd L.	Last Name	Pollard II	Registration Number (If appropriate)	64793

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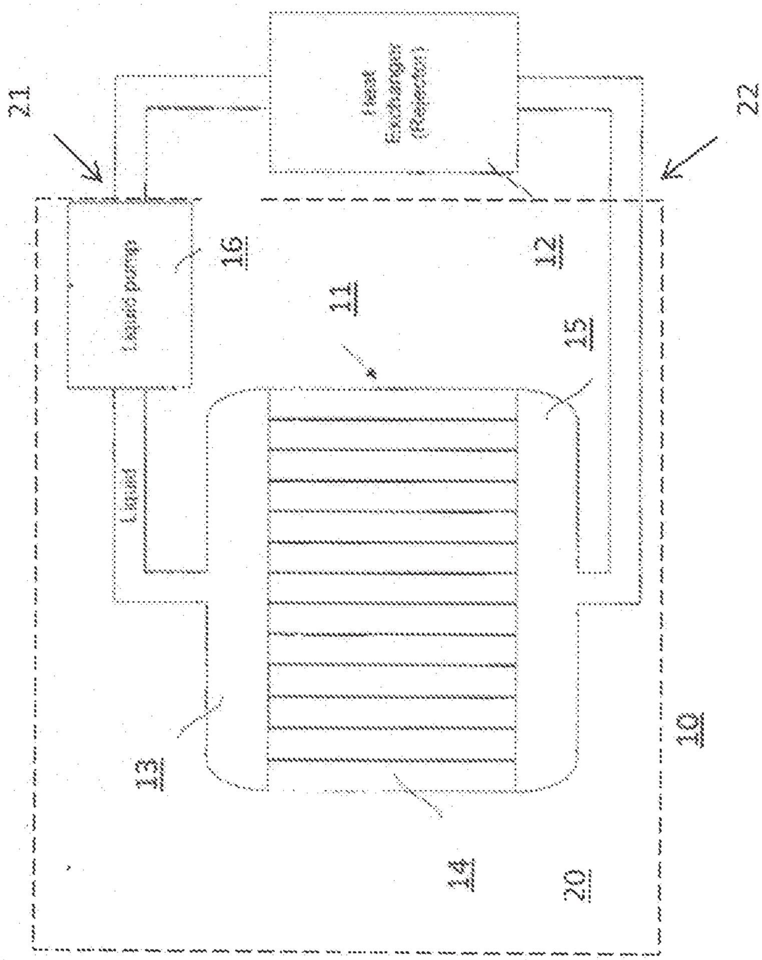

FIG. 1

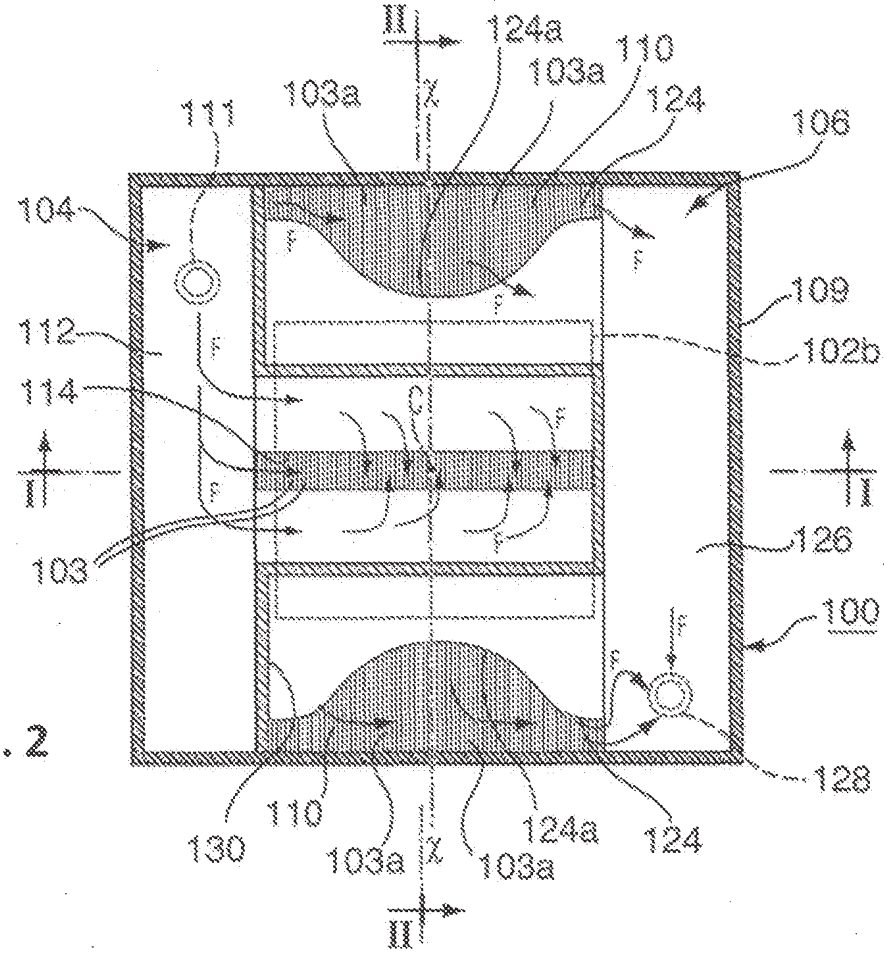

FIG. 2

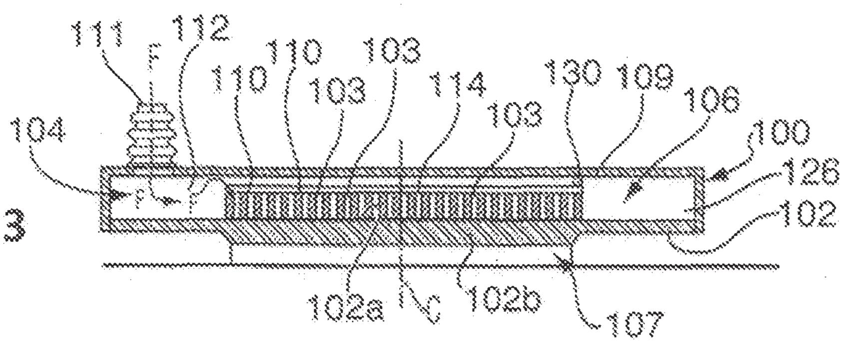

FIG. 3

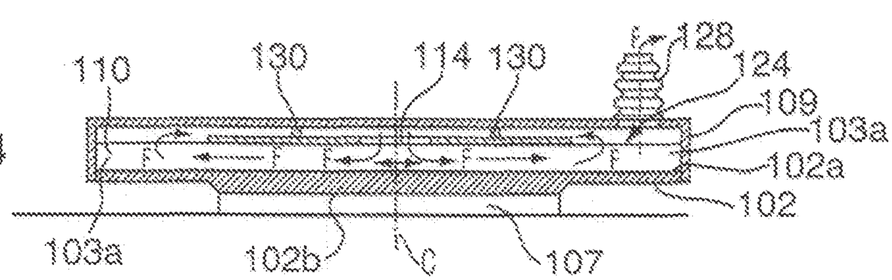

FIG. 4

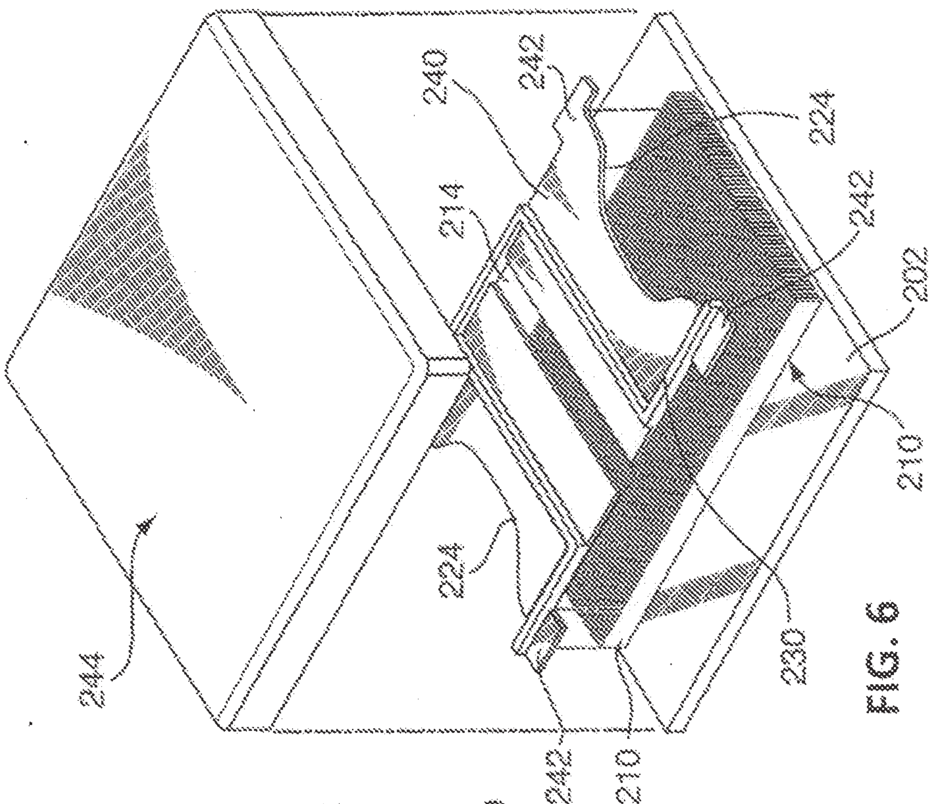
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FIG. 6

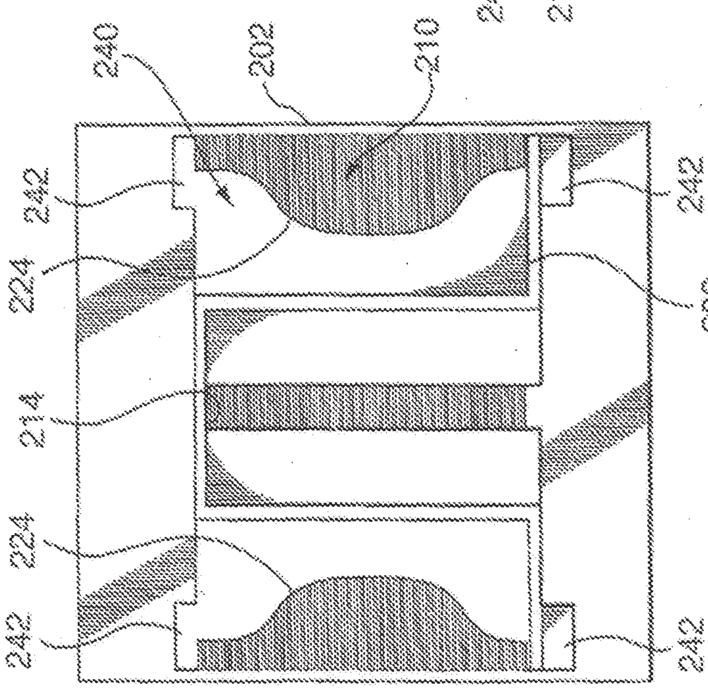
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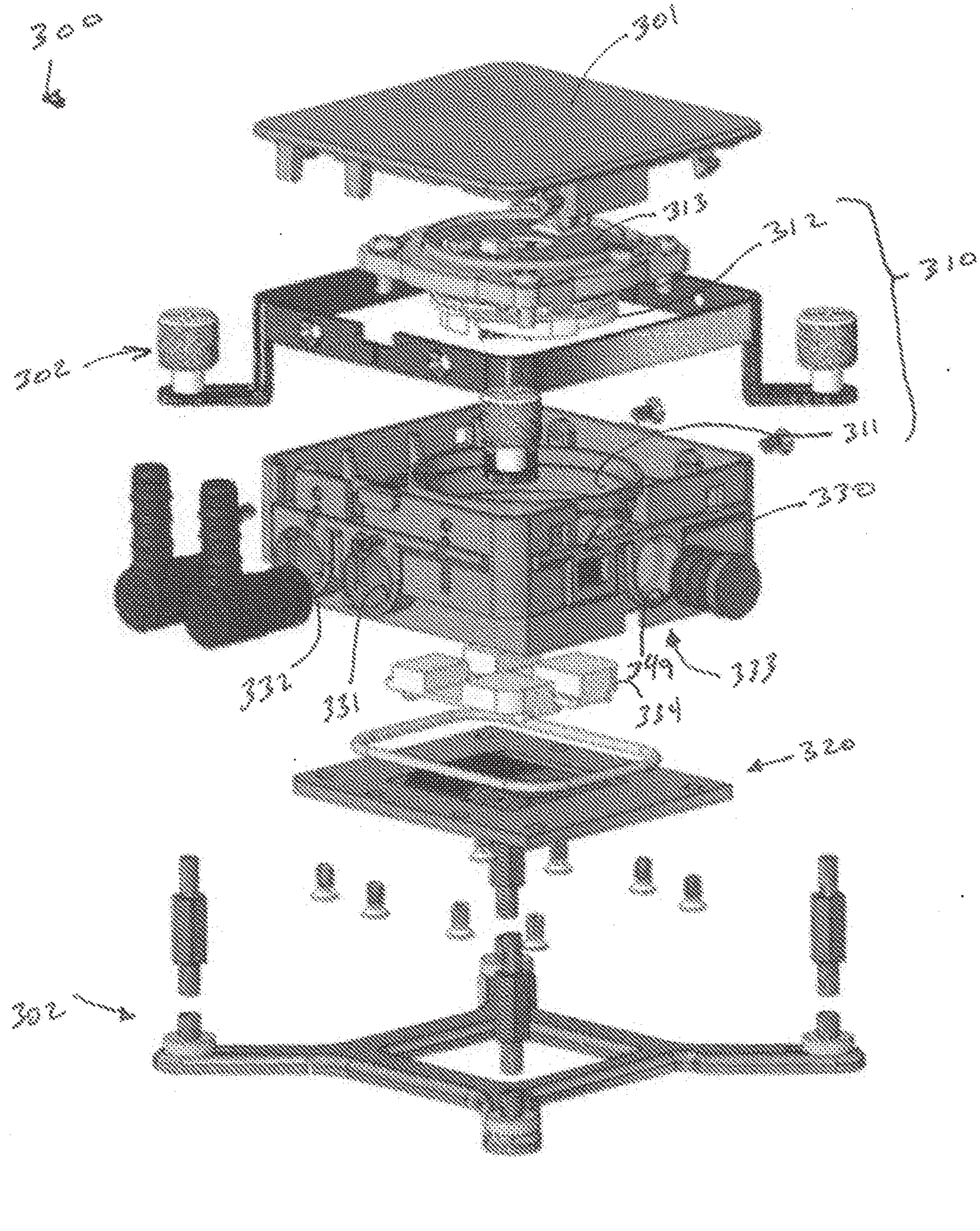
FIG. 5



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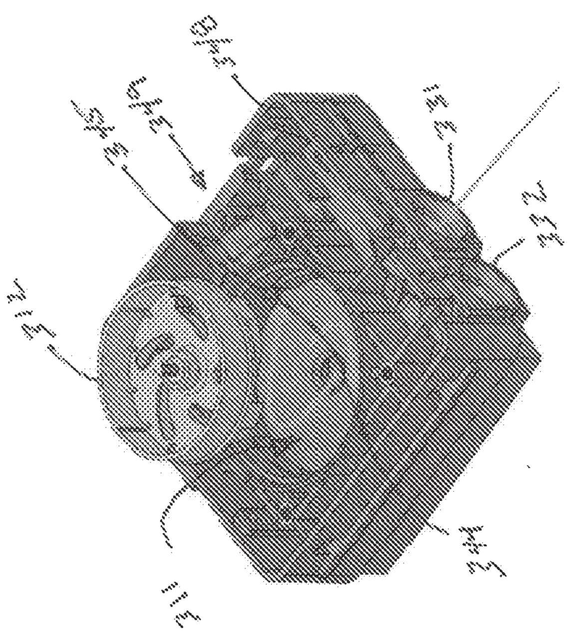

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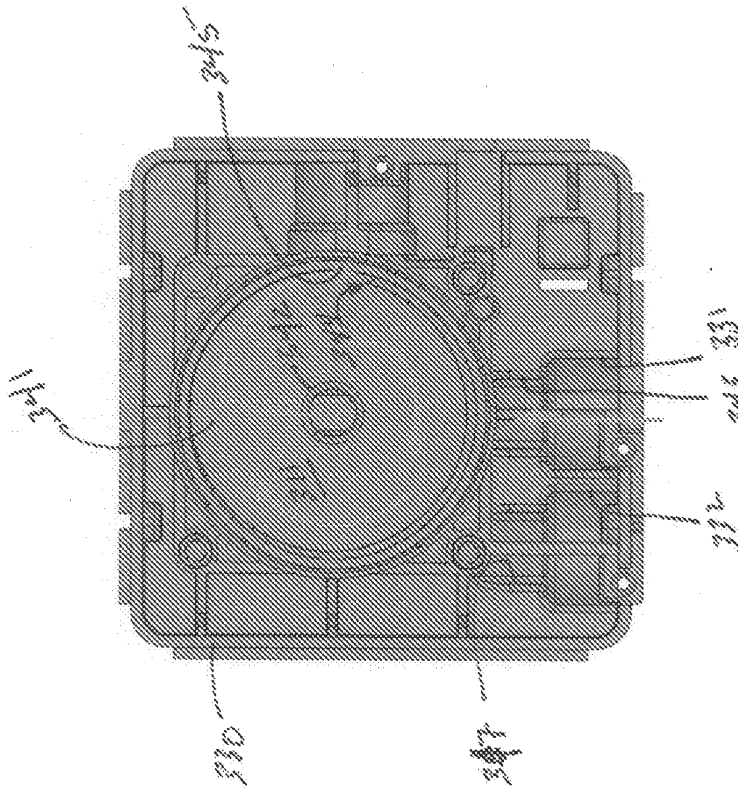

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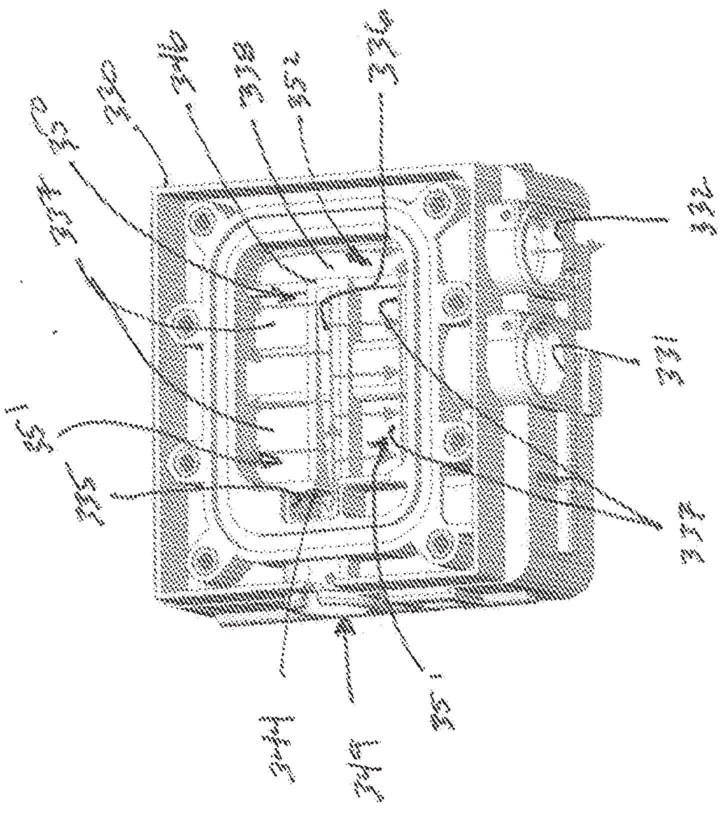

FIG. 10

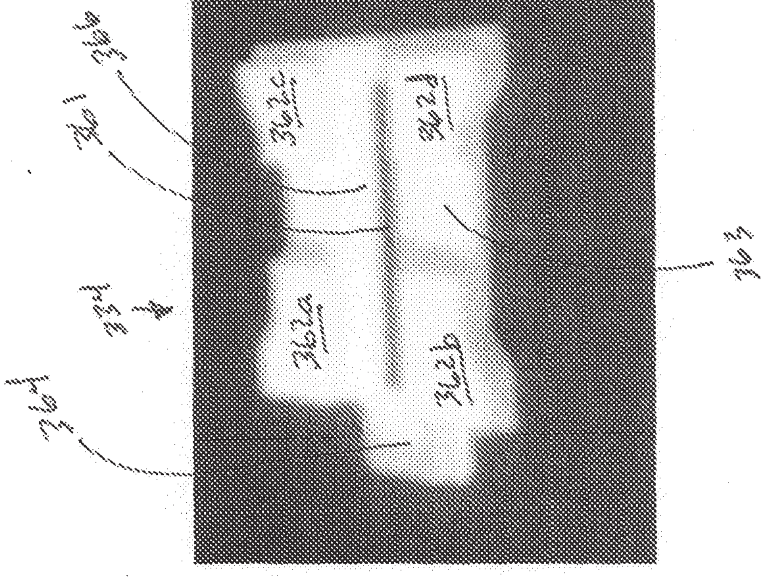

FIG. 12

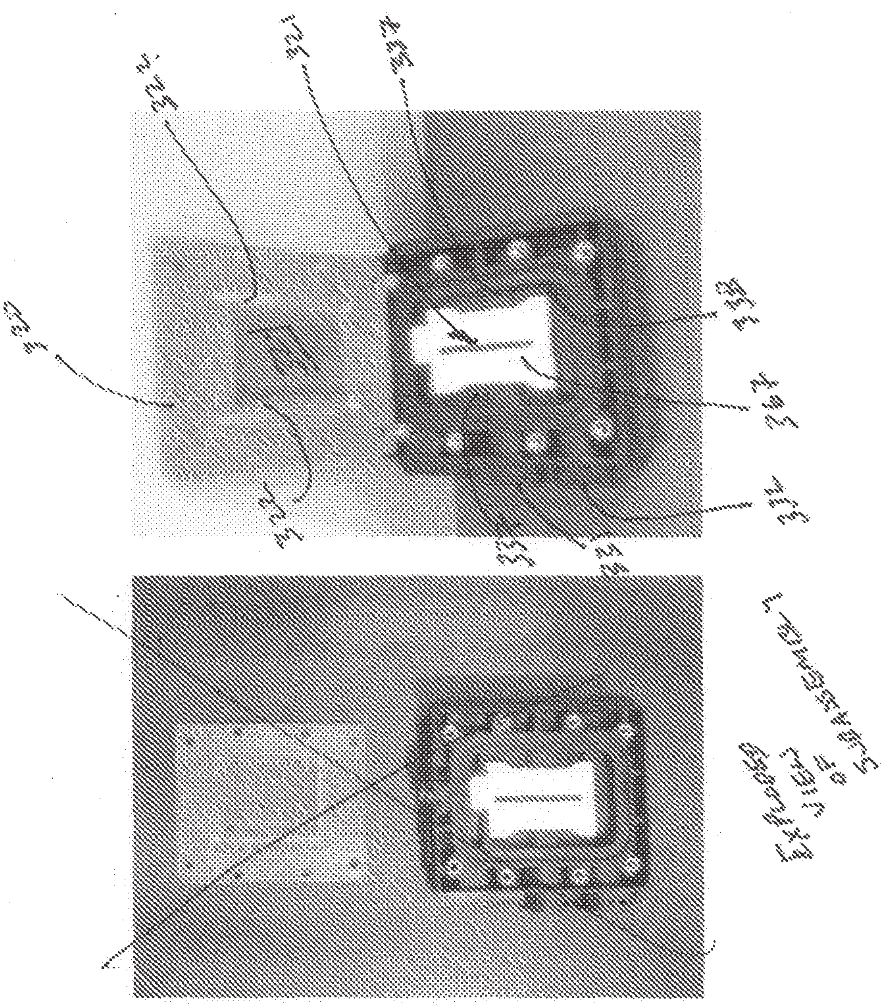

FIG. 11

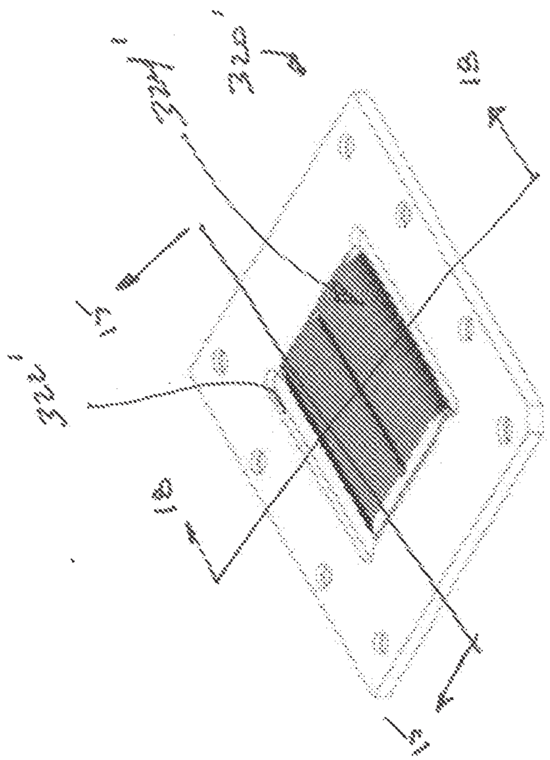

FIG. 14

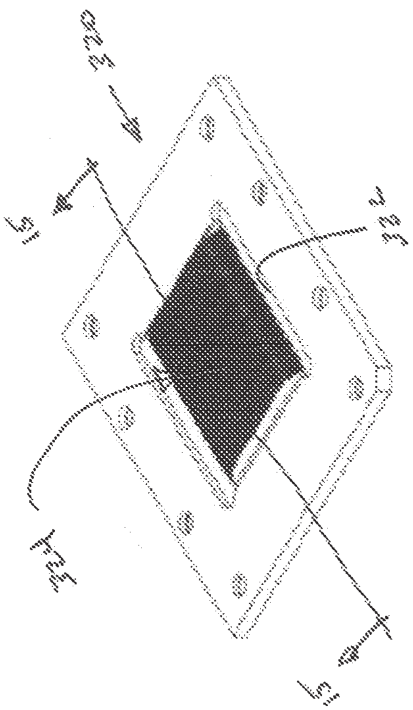

FIG. 13

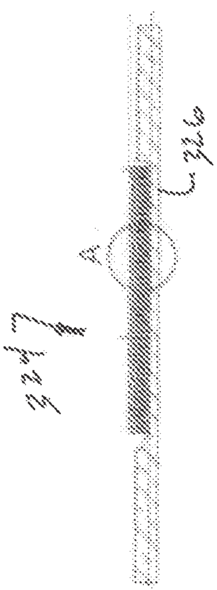

FIG. 15

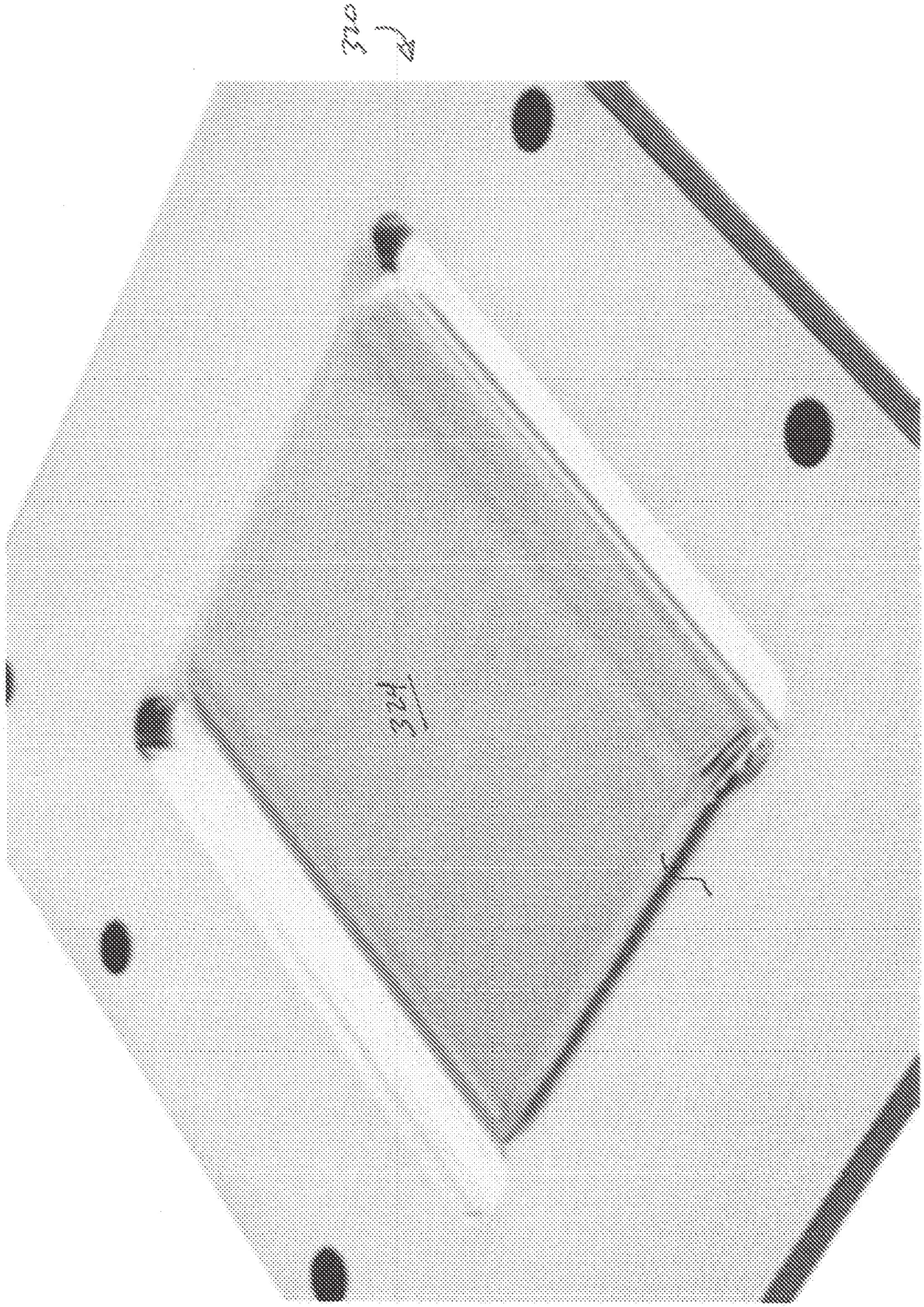

FIG. 13A

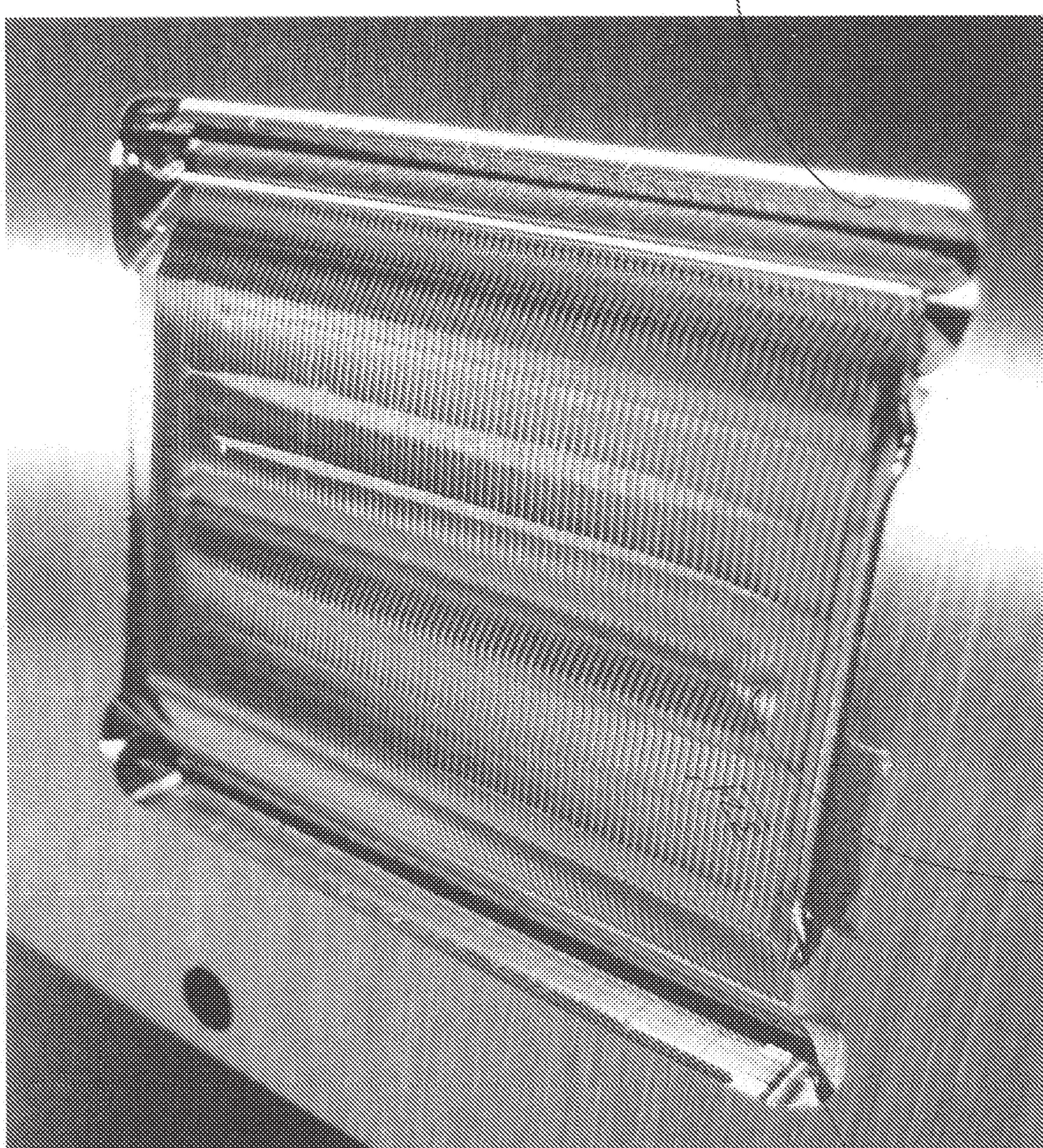

Fig. 14A

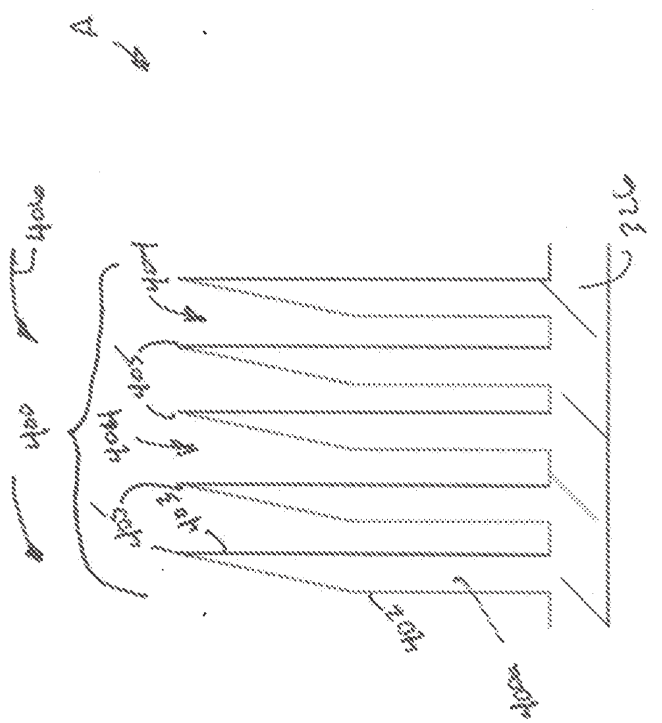

FIG. 16

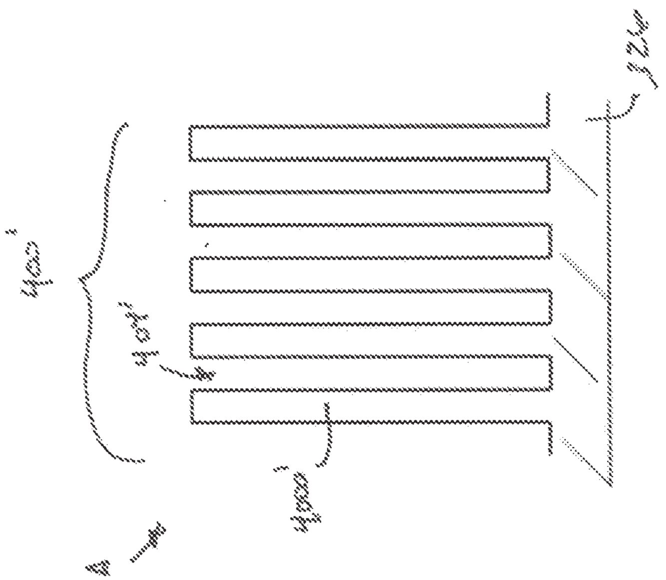

FIG. 17

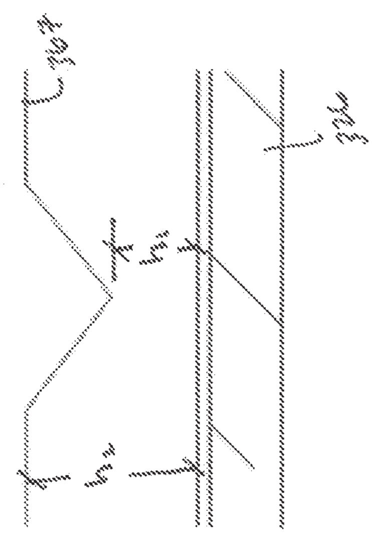

FIG. 18A

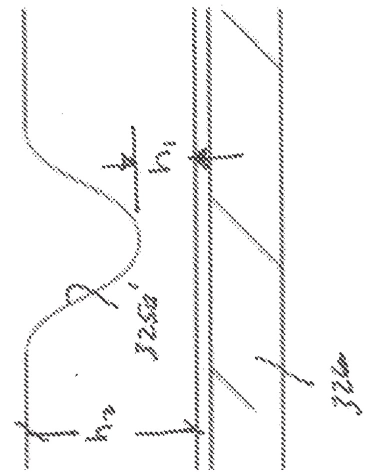

FIG. 18B

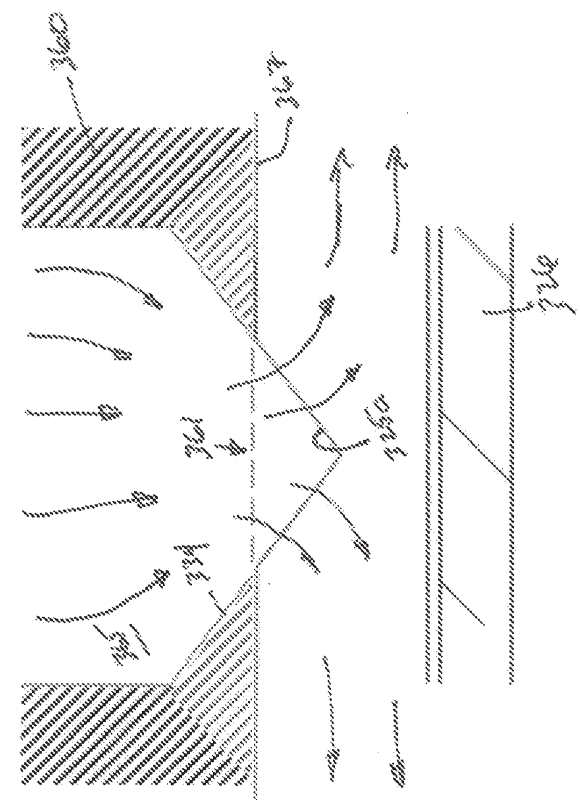

FIG. 19

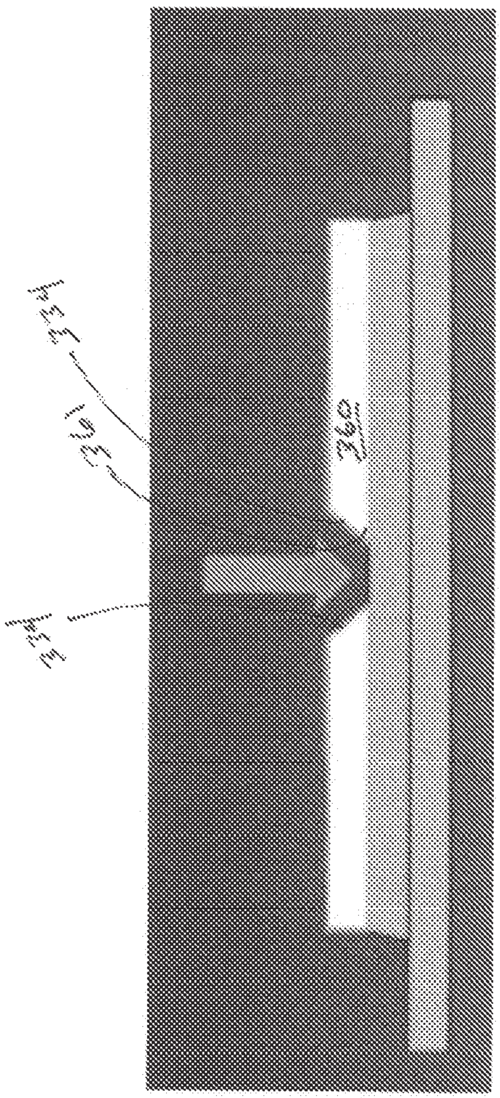

Fig. 19A

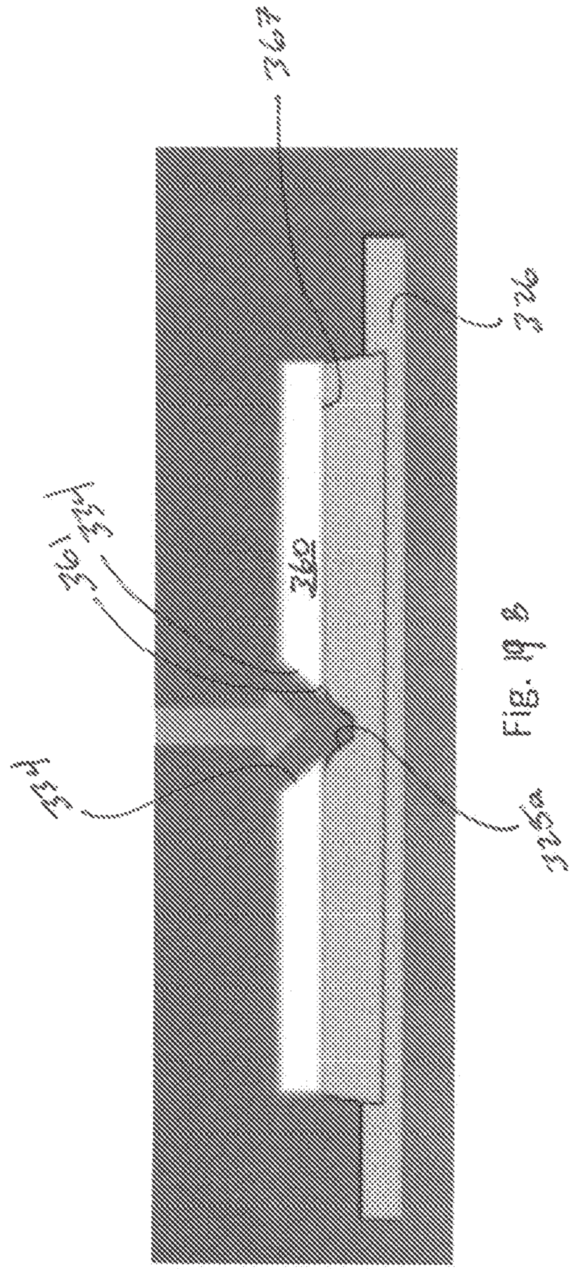

Fig. 19B

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	FLUID HEAT EXCHANGE SYSTEMS
First Named Inventor/Applicant Name:	Geoff Sean Lyon
Filer:	Lloyd L. Pollard II/Tracie Semenchalam
Attorney Docket Number:	COOL-2.001.PR2

Filed as Large Entity

Provisional Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Provisional application filing	1005	1	220	220
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**220**

Electronic Acknowledgement Receipt

EFS ID:	10613980
Application Number:	61512379
International Application Number:	
Confirmation Number:	5992
Title of Invention:	FLUID HEAT EXCHANGE SYSTEMS
First Named Inventor/Applicant Name:	Geoff Sean Lyon
Customer Number:	22874
Filer:	Lloyd L. Pollard II/Tracie Semenchalam
Filer Authorized By:	Lloyd L. Pollard II
Attorney Docket Number:	COOL-2.001.PR2
Receipt Date:	27-JUL-2011
Filing Date:	
Time Stamp:	21:41:38
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$220
RAM confirmation Number	8301
Deposit Account	501001
Authorized User	GANZ,BRADLEY M.

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Specification	SpecificationClaimsAbstract.pdf	172873 eea90bd2ef56a7c6f38ed4d42cb77e41bfaa97b0	no	44
Warnings:					
Information:					
2	Provisional Cover Sheet (SB16)	ProvisionalSB.pdf	1060154 08a37ab70026c327e0d2c59e3b031293ae635e70	no	3
Warnings:					
Information:					
3	Drawings-only black and white line drawings	drawings.pdf	6469108 f9b899f10c6790c3edab887152a4b781a5437fb1	no	13
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4	Fee Worksheet (SB06)	fee-info.pdf	29281 718a32830204de396e029b80a2118163fe06d43d	no	2
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